CHAPTER 3.0

JUST-IN-TIME (JIT) MANUFACTURING SYSTEMS

3.1 Abstract

The Just-In-Time technique based manufacturing system, developed and implemented in the Toyota Motor Company may be defined as manufacturing only the necessary items in exact quantities and at the required time. A study has been carried out to identify the industries design aspects of organization implementing JIT philosophy. Manufacturing Planning and Control systems require adaptation to a better environment, new methodologies for increasing manufacturing efficiency and efficacy. This chapter deals with the study of JIT techniques with a brief discussion on the transferability and the general problems experienced by the manufacturing firms in implementing this in small industries. JIT relies on simple and direct means of manufacturing control and solving problems in shop floor without the assistance of an expert. Study of the Indian Industrial setup indicates that implementation of JIT to adapt to Indian standards is possible by means of technology transfer due to the openness of all the recent policies. A detailed study has been carried out on the Indian industries to have a better knowledge about the implementation of JIT system. This chapter further deals with JIT covering a wide range of techniques and considerations. Moreover, this chapter gives an overview of large number of JIT techniques, their merits, ways of implementation and also the approaches associated with JIT. A comparison between JIT and synchronous manufacturing is also presented.

3.2 Introduction

JIT is not a technique, it is a goal [48]. Western countries are scrutinizing the Japanese techniques of Industrial Management closely to account for the radical change of Japanese product in the international market. Japanese techniques are very pleasing for the developed nations. They are much more

demanding for the developing and underdeveloped nations, because basic simplicity and low requirements for staff expertise and capital investment are the features of JIT. JIT does not require computers; it does not require high capital systems and material handling devices. This is applicable to most of the developing nations such as India to impart JIT techniques with a sufficient knowledge on these techniques. JIT relies on simple and direct means of manufacturing control and solving problems in shop floor without the assistance of an expert. Further JIT with Total Quality Control (TQC) on a small lot manufacturing system exposes defectives early so that diagnosis and correction may proceed on the early stages of the manufacturing.

3.3 Just-In-Time (JIT) Systems

"Produce and deliver finsihed goods just in time to be sold; subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies and purchased material just in time to be transformed into fabricated parts" [74]. Monden [64] explains JIT as " to produce necessary units in necessary quantities at the necessary time". The purpose of JIT is to produce a unit, such a way that there is only one unit of work in process and minimum stock of finished goods in inventories. Excess inventories invite troubles and bad causes. Those goods, which are to be consumed only, are to be produced and replaced. Based on the above idea, system has to be developed to produce one unit just in time to go into the next process in an ideal situation. An ideal situation is near about impossible, and even Japanese firm has not attained such a situation. They work aggressively to get as close as possible to stockless production.

3.4 Reduction of Inventory through JIT

Many authors have published research papers on JIT and emphasized the importance of JIT in reducing the inventory level in any manufacturing system and this has been explained in Chapter 2 (refer to 2.3). The competition in the world of liberalization and globalization requires drastic changes in the Indian

scenario. This needs introduction and implementation of Japanese technique like Just-In-Time (JIT) considering the constraints, shortcomings and crisis to Indian industries. This chapter is only an attempt to adopt JIT technique, which will change the way the modern industries operate. In many industries, JIT implementation has been conscious ongoing exercise for quite sometime. Factors like distance, storage requirements, and problems of transportation are some of the constraints likely to arise if JIT is ignored and given not due consideration. JIT deliveries involve getting exactly the right amount of items at exactly the right place at just the right time. The JIT philosophy basically aims to achieve Five zeros.

- *Zero inventory*
- *Zero defect*
- *Zero Material handling*
- *Zero Lead time*
- *Zero Setup time*

The primary goal of JIT is to promote better better, faster customer service while reducing inventory and labour costs. This is accomplished by reducing the amount of Work-In-Process (WIP) on the shopfloor and shortening cycle times. There are several policies and methods, companies use to achieve a successful JIT program. Some simplify bills of materials and part routing. Some have eliminated work orders. Setup times between jobs have been minimized to further reduce cycle times.

JIT also helps produce goods economically, quickly and safely. The structure of JIT is designed based on the factor that significant cost saving can be achieved by producing the necessary quantities. This can emerge into a pull system wherein the subsequent station waits for the preceding station to perform the operation to cater to the demand. This can be done effectively by proper line balancing the operations in the manufacturing line.

JIT employs a combination of several elements. These elements include smoothing of production, provision for process flexibility, standardization of jobs and information-carrying cards called *kanban*.

- Reduction in setup time leads to smooth production process. Japanese experience is that a reduction in setup time and lot size has a significant improvement in the quality, scrap and worker motivation. This also brings about reduced storage and material handling facilities along with capital investment.
- Yet another step to achieve JIT environment is to engage multifunctional workers capable of performing more than one operation such as workers performing maintenance along with quality inspection process. This not only reduces the number of workers in the setup but also improves the productivity of the system. The overview of JIT system is shown in Fig.3.1

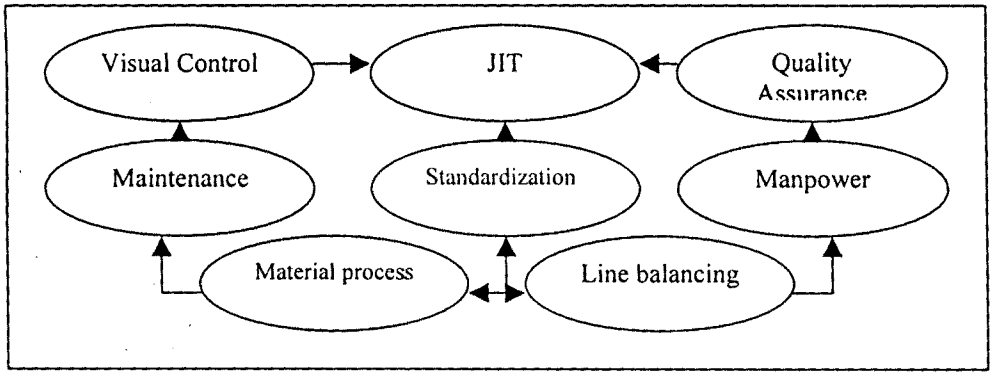


Fig. 3.1 Overview of JIT

- Standardization of jobs is also a characteristic of JIT system. Standard cycle time, standard routing and standard quantities are some of the factors under consideration for standardization of the job, which leads to uniformity in output, minimum quantity of work in process inventory.
- Kanbans are information carrying cards used in JIT to perform the scheduling. The production ordering kanbans show the quantity of parts, which the

preceding operation must produce. When the product or part is used for transportation, the production ordering kanban attached on to the product or part is removed and used to order the movement of the product or part to the production process. The withdrawal kanban, which gives the details of the quantity of the parts, which the subsequent process, should withdraw from the buffer stock before each manufacturing process. The total inventory level is the total sum of the kanbans attached to the containers at each stage. This is pull system wherein the subsequent station waits for the preceding station to perform the operation to cater to the demand. This can be done effectively by proper line balancing the operations in the production line.

3.5 Waste Elimination through JIT

The expanding implementation of JIT approach to manufacturing management has resulted in additional demands being placed in vendors. The JIT concept is based on a philosophy and strategies outlining the elimination of waste where waste is defined as anything other than the minimum resources required to add value to the product. This typically focuses on the reduction of inventory levels. A large number of manufacturing companies are discovering that traditional, financially oriented performance measures are impeding the attainment of JIT's potential benefits. For JIT to be successfully implemented, the performance measurement system must support the JIT manufacturing environment. Traditional performance measures do not often support a JIT manufacturing environment because they are financial in nature and relate to external reporting requirements. They are not reported on a timely basis and encourage short term rather than long term behaviour.

3.6 Performance Measurement Linkage

JIT is only one element or goal, which will be the outcome of a concept. It can harness the resources of everyone to work towards making the company the best in its business. The concept behind this achievement is known as company-

wide quality improvement. Fig.3.2 explains the performance measurement linkage in a general manufacturing system.

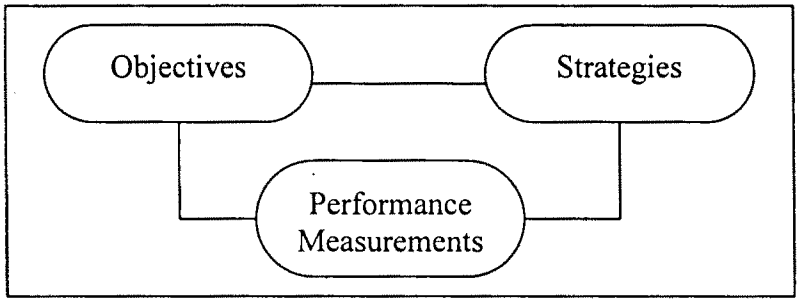


Fig. 3.2 Performance Measurement Linkage

The real goal of JIT can only be achieved when JIT is working throughout the length of the entire supply chain. For this reason, customer/supplier relationship is a key feature in the achievement of JIT. JIT is also comparable with Supply Chain Management (SCM).

3.7 JIT related concept

- JIT is an objective. To achieve this objective, it is necessary to evolve, develop and integrate many concepts and techniques and to begin changing the culture of the company.
- These concepts are embraced within the overall concept of company-wide-quality improvement.
- The objective of company-wide quality improvement is to create an organization in which every employee from top to bottom is working towards making that organization the best in its particular field. It is based on the idea that each person is an expert in his or her own job and by harnessing the collective thinking power, creativity and job knowledge of everyone in the organization to compete with other organizations.

To achieve JIT, it becomes necessary to find ways of tackling these chronic problems on a project by project basis. This means that all established

norms must be challenged. There can be no standard level of bufferstock, finished goods stock, work-in-process, machine availability and design modification and so on.

Planning and scheduling concepts based on forecasting are limited in their applicability to the achievement of JIT. The main effort must be to improve the rate of response of the system to sudden changes in demand. JIT requires defect levels measured in part/millions levels. Defects in parts/million cannot be achieved simply through the application of traditional methods such as sampling and batch inspection. It requires the intensive application of quality sciences and disciplines.

The JIT approach to managing industrial operations and the techniques associated with it have to do with minimizing manufacturing lead times. The result is an alternate way of looking at JIT, which has the following managerial, theoretical and engineering implications.

- *It brings out the relationship between operations and customers.*
- *It demonstrates that manufacturing has revenue-enhancing features*
- *It provides simple framework that may help industrial engineers and managers conceptualize JIT.*

3.8 Implementation of JIT

A survey was conducted for the purpose of implementation of JIT in developing countries. The study was carried out in Indian subcontinent with focussing mainly on small and medium scale industries. The existing Indian Industrial setup implies that technology transferability from the developed countries is not a one to one process and that it has to undergo various changes to adapt to the existing culture. On the basis of the survey, under-utilization of both worker and machine, inferior quality, unreliable long lead time, high rate of scrap and rework, poor maintenance policy, improper inventory, shortage of skilled workers, low productivity are some of the factors which are prevailing in the

industries hindering the process of implementation of JIT in Indian environment. In the present setup, under-utilization of resources is prevailing to a greater extent. For example, each worker is allocated with a specific work. The worker tends to be idle until the assigned job reaches him. During this idle time, if he is trained to carry out other allied operations such as follow up of the material under process or maintenance, this would keep the worker and the equipment busy, and thereby a better productivity is achieved. Shortage of raw material is an acute problem faced in the industries. Although there are various factors, which lead to these conditions, proper purchase policy and vendor development programmes can help in minimizing this condition. The quantum of rework and scraping in medium and small-scale industries are very high. This is because of low investment and wrong quality control techniques followed by the industry. Implementing TQC can bring down rework and scraping down of defective parts. This can also help to meet out the raw material shortage.

Shortage of skilled worker in the present setup hinders process of implementation of JIT to a greater extent. More than skilled worker, to implement JIT the system demands for multi-functional workers who can perform more than one activity successfully as shown in Fig. 3.3. Making the workers and foreman knowledgeable by means of training and educating them to dedicate themselves for a better manufacturing could develop this. Introduction of simpler machines with simple operation conditions will bring about reduction in skilled workers requirment. Undefined/uncertain quality management has been the cause for inferior quality of products produced in this setup. With the introduction of TQC along with controlled material holding and production can be the key for eradication of quality problems. JIT deals with quality problem very naturally. JIT recommends small lot size of production, which enables to identify errors quickly. Imparting quality measurement skills to the production people, analyzing defects etc., are some of the skills developed by the Japanese foremen and workers.

Reducing the setup time and lot size of the component can cut down unreliable long lead time. When the lot size is small, the time taken to process the same on a machine is small when compared with that of a larger lot size which means the successive machine has to wait for a longer time for the arrival of the material to be processed. Also reduction in lot size enables easy and quicker material handling. Constituting a better purchase policy and developing good vendors who adopt JIT policies can bring down purchase lead time. Multi-functional workers and group technology provide flexibility so that lead times are more reliable. Industries engage a separate maintenance department to carry out the maintenance of the machine. This leads to both machines lying idle waiting for the maintenance and overheads incurred due to managing a separate maintenance department. The concept of multi-functional workers in JIT enables the worker to clean up their own and carry out the maintenance at the end of the work schedule.

3.9 Preliminaries of JIT Manufacturing

In order to implement JIT manufacturing effectively, the following conditions should first be imposed.

- *Standardization of the individual operation*
- *Provision for U-shaped layouts as shown in Fig. 3.3 such that each operator can handle more than one machine.*
- *Multiple job work by each operator, Job allotment to each individual operator changes frequently (eg., every week) ; every operator is required to master multiple jobs. Again there are implications for job enrichment and satisfaction.*
- *Reduction in setup times. A typical objective requires that setup is completed within ten minutes (called single setup). This may reduce batch sizes and work-in-process inventories*

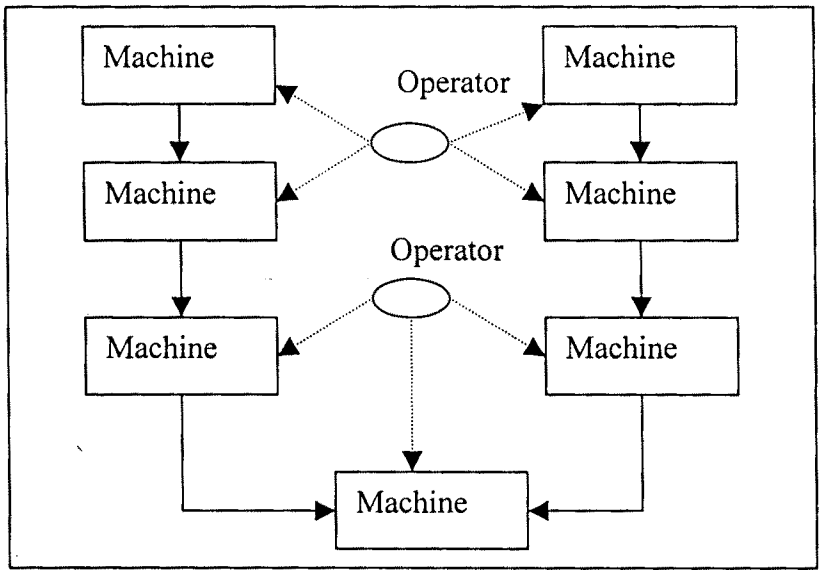


Fig. 3.3 U shaped Plant layout

- *Manufacturing smoothing by providing master production schedule as shown in Fig.3.4. JIT manufacturing is a method of coping with inefficient multi-product, small batch manufacturing. It should be noted that JIT principle using pull-through system has been employed in supermarkets for many years.*

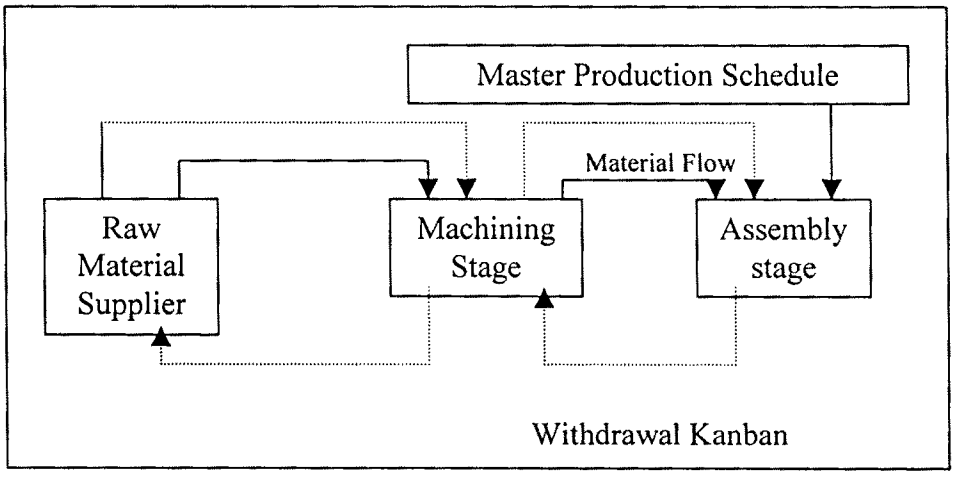


Fig. 3.4 Master Production Schedule

Table 3.1 presents a list of problems, their causes and the advantages of implementing JIT policy in overcoming these problems. These have been collected based on a survey made in certain industries.

Table 3.1 A list of problems, their causes and the advantages of implementing JIT policy in overcoming these problems.

S.No	Nature of Problem	JIT
1	*Under utilization of men and machines*	*Multi-functional workers with a good layout of machines can increase the production rate*
2	*Raw material shortage*	*Improving vendor development activities and formulating good purchase policies*
3	*High rate of rework or scrap*	*Small lot-size enables prevention of long run defective components.*
4	*Shortage of skilled workers*	*Induction of training programme to workers along with simplified operations*
5	*Unreliable long lead time*	*Quick setups can cut lead time and improve productivity*
6	*Poor and improper maintenance*	*Principle of multi-functional workers helps in maintaining the machine and the workplace clean and good.*

3.10 Issues of JIT Manufacturing

It is commonly believed that JIT manufacturing is very efficient; however, several issues of demerits are pointed out as follows.

- JIT manufacturing is effective only when the daily demands and daily manufacturing are fairly stable.
- The cycle time for assembling is set by

  Cycle time = daily operating hours/daily manufacturing volume where

Daily manufacturing volume = monthly manufacturing volume required /monthly workdays. Hence JIT manufacturing is effective if there is no variation of daily manufacturing and if manufacturing volume and capacity are well balanced.

- The minimum or zero inventory cannot be theoretically achieved; Many medium/small companies supplying to large companies are required to hold stocks of parts in order to assure JIT delivery to them.
- No consideration is given to optimum dynamic scheduling; only the first-in, first-out principle is applied by manufacturing items in the order of releasing kanbans.
- Much needs to be done in connection with employer-employee cooperation, daily workstation rotation, training of operators for different kinds of jobs and the system's adaptability to market fluctuation. Without the service of subcontract factories this manufacturing system may not work at all.
- A particular social issue arises from the frequent transportation of part/products required to assure JIT delivery. It causes air pollution, noise, and traffic problems, which are against the ideas of manufacturing excellence.

3.11 Repetitive Systems

It is technically possible to install repetitive system without any concern for JIT. If this is done, the company is likely to wind up with as much work-in-process inventory and as many record keeping transactions as it has originally. The reason for this is that the disciplines needed to implement and maintain a repetitive system are very closely allied to JIT. Balancing the work centres really requires that only enough inventory to sustain the flow rate for that line be available on the shop floor. JIT projects are being launched in most of the better known industrial firms in the world.

3.12 Total Productive Maintenance

The operation of a JIT manufacturing control system mainly depends on the performance and availability of resources. The effectiveness of manufacturing equipment and other resources on the line is maximized by Total Productive Maintenance (TPM) which mainly depends on the preventive maintenance

system. These activities must be carried out at each level and each stage of the JIT system to increase the system performance. Since a good maintenance program has a great impact on machine reliability and availability on which JIT system is considerably dependent, there is a strong need for maintenance policy analysis to obtain a better system design and operation.

3.13 Types of Kanban

The master manufacturing plan is given only to the final stage of the whole manufacturing process. In this, workers perform the required work on the material provided by the preceding workstation at the necessary time and hence called pull system. To provide information, two kinds of kanban (Instruction card) are used. These are "Withdrawal" and "Manufacturing Ordering" information.

Withdrawal kanban indicates that the item and their quantities are to be brought from the previous stage to the current workplace. Once the Kanban is issued, the items and their quantities indicated on the kanban are withdrawn and brought to the current workplace together with the *kanban.*

The manufacturing kanban is taken from the box, which has stored the item parts withdrawn from the next stage. According to instructions indicated by this manufacturing kanban, manufacturing starts and continues until the quantities of the withdrawn parts have been completely replenished.

3.14 Comparison of JIT with Synchronous Manufacturing

On comparison of JIT with synchronous manufacturing, JIT does an excellent job in reducing lead times and work-in-process, but it has several drawbacks [20].

- *JIT is limited to repetitive manufacturing*
- *JIT requires a stable manufacturing level (usually about a month long)*
- *JIT does not allow very much flexibility in the products manufactured. (Products must be similar with a limited number of options)*

- *JIT still requires work-in-process when used with kanban so that there is "something to pull". This means that completed work must be stored on the downstream side of each workcentre to be pulled by the next workcentre.*
- *Vendors need to be located nearby because the system depends on smaller, more frequent deliveries.*

Since synchronous manufacturing uses a schedule to assign work to each workcentre, there is no need for more work-in-process other than that being worked on. The exception is for inventory specifically placed in front of a bottleneck to ensure continual work or at specific points downstream from a bottleneck to ensure flow of product.

Concerning continual improvements on the system, JIT is a trial and error procedure applied to a real system. In synchronous manufacturing, the system can be programmed and simulated on a computer since the schedules are realistic (can be accomplished) and computer run time is short.

3.15 Conclusion

Many medium and small-scale industries need a long way to go in the path of JIT. Only a few companies have started developing and implementing JIT. Another problem related to JIT concept is machine selection. This requires the determination of the number of machines for each stage of the manufacturing process. Empirical studies on JIT implementation in manufacturing have been done more recently. It is also impossible to envision all possible future research directions because JIT implementation is limited to small size. Attempts have been made to study the transfer of Japanese technology to developing countries. Developing countries desparately need undergo a radical change in their system of managing the industry to improve the quality and productivity of their goods to survive and compete in the international market. The chief obstacle to rapid adoption of JIT is training. The concept of multi-functional workers with

dedication towards growth of the company is a key factor for the successful implementation of JIT. Implementation of JIT could only be possible if both the workers and the management take up this issue seriously.

In this chapter, JIT concept is discussed in detail and a few literatures on the same are indicated. It is also explained how the introduction of JIT concept helps in reducing the inventory level in a manufacturing organization. The overview of JIT philosophy is discussed and the role of JIT concept relating to performance measurement is also presented. Further, the details explaining how JIT methodology has been implemented in developing countries are highlighted through the help of a survey made. Again, information about the types of problems many organizations are experiencing in the present days of manufacturing scenario, how these problems can be overcome by the implementation of JIT philosophy and the remedies that could be thought of have been enlightened for better understanding of the JIT concept. It is also explained how the layout of the shop floor should be designed for effective utilization of manpower and machineries so as to meet the MPS. The maintenance activities that could be carried out in a JIT-implemented enterprise and the types of kanbans used for effective flow of information within the shop floor are also presented. A comparison between JIT system and synchronous manufacturing system is also explained. **To obtain the real performance measures of the manufacturing system, synchronous manufacturing principle has been selected and explained in the subsequent chapters.**

Shop Floor Control

Even a journey of one thousand li begins with a single step.

– Lao Tze

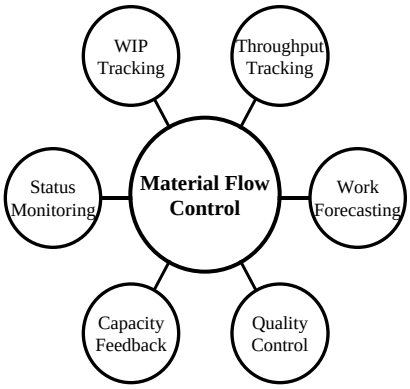
It is a melancholy thing to see how zeal for a good thing abates when the novelty is over, and when there is no pecuniary reward attending the service.

– Earl of Egmont

What is Shop Floor Control?

Definition: ***Shop Floor Control (SFC)*** is the process by which decisions directly affecting the flow of material through the factory are made.

Functions:



Planning for SFC

Gross Capacity Control: Match line to demand via:

- Varying staffing (no. shifts or no. workers/shift)
- Varying length of work week (or work day)
- Using outside vendors to augment capacity

Bottleneck Planning:

- Bottlenecks can be designed
- Cost of capacity is key
- Stable bottlenecks are easier to manage

Span of Control:

- Physically or logically decompose system
- Span of labor management (10 subordinates)
- Span of process management (related technology?)

Basic CONWIP

Rationale:

- Simple starting point
- Effective in some environments

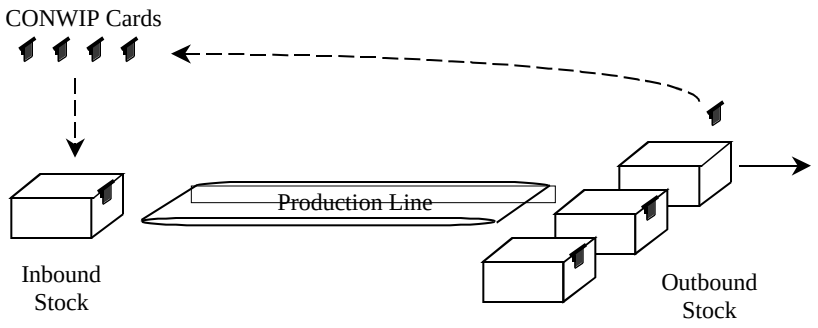
Requirements:

- Constant routings
- Similar processing times (stable bottleneck)
- No significant setups
- No assemblies

Design Issues:

- Work backlog – how to maintain and display
- Line discipline – FIFO, limited passing
- Card counts – WIP = CT × r_P initially, then conservative adjustments
- Card deficits – violate WIP-cap in special circumstances
- Work ahead – how far ahead relative to due date?

CONWIP Line Using Cards



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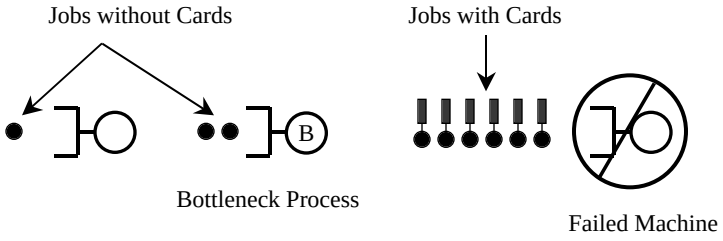
Card Deficits



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Tandem CONWIP Lines

Links to Kanban: when "loops" become single process centers

Bottleneck Treatment:

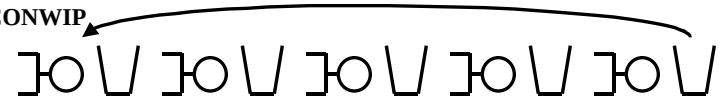
- Non-bottleneck loops coupled to buffer inventories (cards are released on *departure* from buffer)
- Bottleneck loops uncoupled from buffer inventories (cards are released on *entry* into buffer)

Shared Resources:

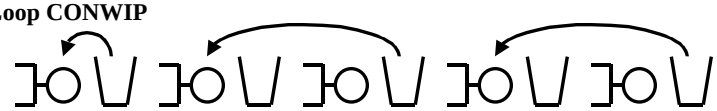
- Sequencing policy is needed
- Upstream buffer facilitates sequencing (and batching if necessary)

Tandem CONWIP Loops

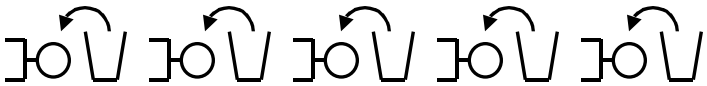
Basic CONWIP

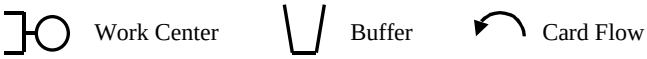


Multi-Loop CONWIP

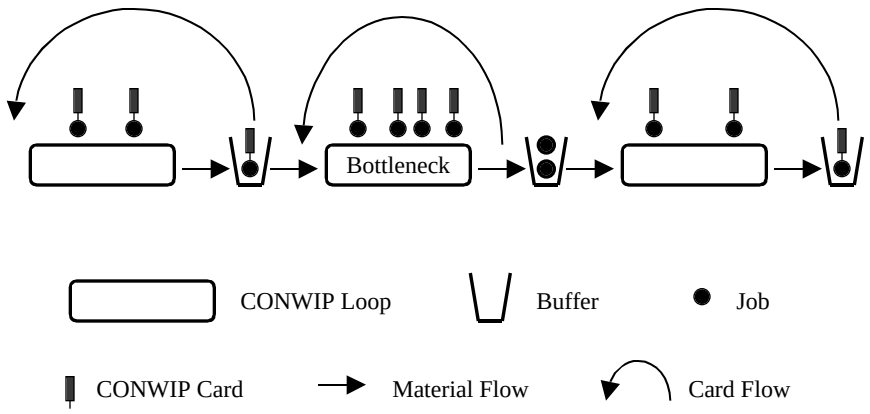


Kanban





Coupled and Uncoupled CONWIP Loops



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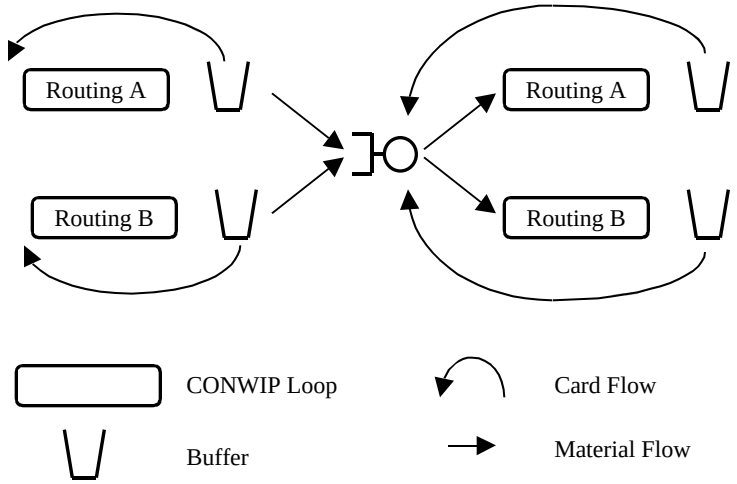
Splitting Loops at Shared Resource



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Modifications of Basic CONWIP

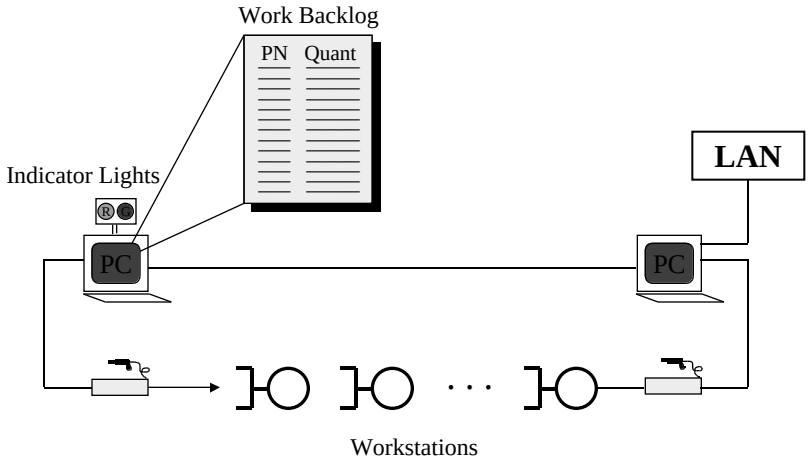
Multiple Product Families:

- Capacity-adjusted WIP
- CONWIP Controller

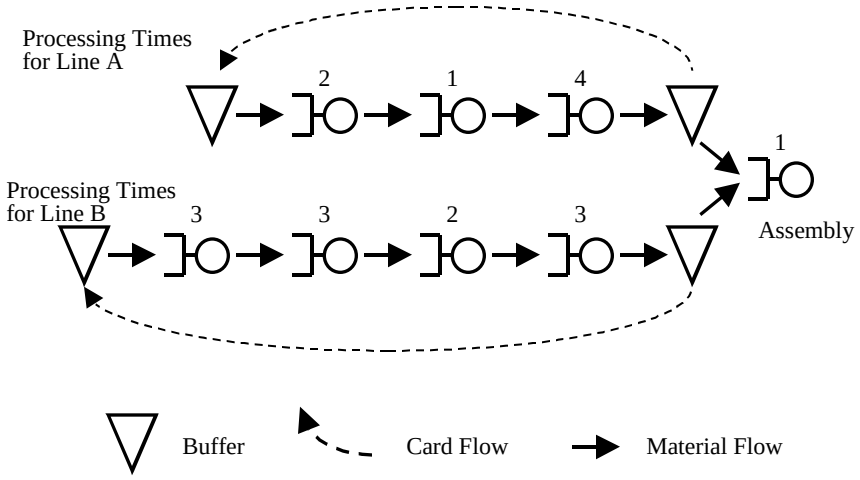
Assembly Systems:

- CONWIP achieves synchronization naturally (unless passing is allowed)
- WIP levels must be sensitive to “length” of fabrication lines

CONWIP Controller



CONWIP Assembly



Kanban

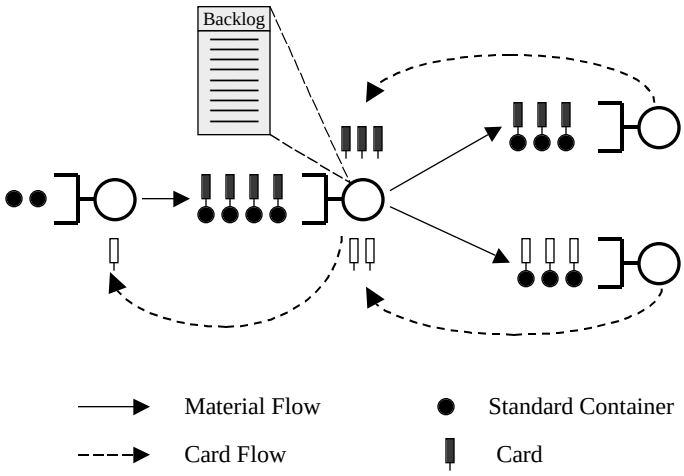
Advantages:

- improved communication
- control of shared resources

Disadvantages:

- complexity – setting WIP levels
- tighter pacing – pressure on workers, less opportunity for work ahead
- part-specific cards – can't accommodate many active part numbers
- inflexible to product mix changes
- handles small, infrequent orders poorly

Kanban with Work Backlog



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Pull From the Bottleneck

Problems with CONWIP/Kanban:

- Bottleneck starvation due to downstream failures
- Premature releases due to CONWIP requirements

PFB Remedies:

- PFB ignores WIP downstream of bottleneck
- PFB launches orders when bottleneck can accommodate them

PFB Problem:

- Floating bottlenecks

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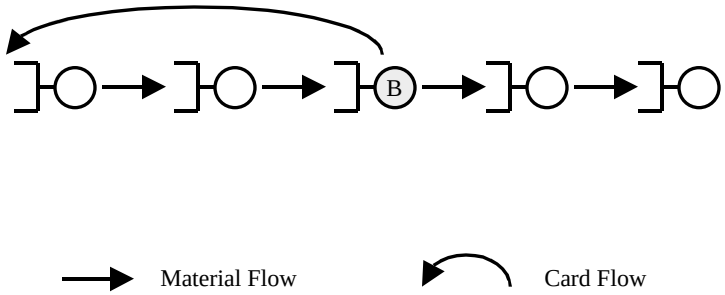
Simple Pull From the Bottleneck



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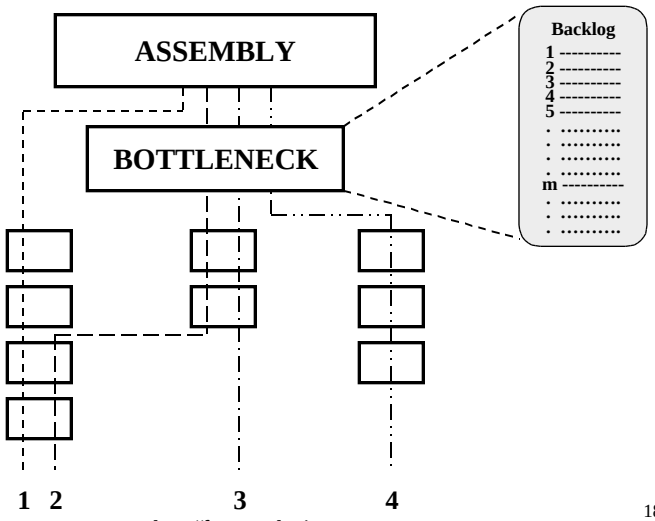
Routings in a Jobshop



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Implementing PFB

Notation:

b_i = The time required on the bottleneck by job i on the backlog.

ℓ_i = The average time after release required for job i to reach the bottleneck.

L = The specified time for jobs to wait in the buffer in front of the bottleneck.

Work at Bottleneck: total hours of work ahead of job j is

$$\sum_{i=1}^{j-1} b_i$$

Job Release Mechanism: Release job j whenever

$$\ell_j + L \le \sum_{i=1}^{j-1} b_i$$

Enhancement: establish due date window, before which jobs are not released.

Production Tracking

Short Term:

- Statistical Throughput Control (STC)
- Progress toward quota
- Overtime decisions

Long Term:

- Long range tracking
- Capacity feedback
- Synchronize planning models to reality

STC Notation

R length of regular time

μ mean production during regular time

σ standard deviation of regular time production

Q production quota

N_t production in $[0, t]$

Y_n time to make quota in n^{th} regular time period

μ_S mean time to make quota, $E[Y_n]$

σ_S std dev of time to make quota, $\sqrt{Var(Y_n)}$

STC Mechanics

Assumption: N_t is normally distributed with mean $\mu t/R$ and variance $\sigma^2 t/R$.

Implications:

- $N_t - Qt/R$ is normally distributed with mean $(\mu - Q)t/R$ and variance $\sigma^2 t/R$.
- N_{R-t} is normally distributed with mean $\mu(R - t)/R$ and variance $\sigma^2(R - t)/R$.
- If $N_t = n_t$, where $n_t - Qt/R = x$, then we will miss quota only if $N_{R-t} < Q - n_t$.

Formula: The probability of missing quota by time R given an overage of x is

$$
\begin{aligned}
P(N_{R-t} \le Q - n_t) &= P(N_{R-t} \le Q - x - Qt/R) \\
&= P(N_{R-t} \le Q(R-t)/R - x) \\
&= \Phi\left(\frac{(Q-\mu)(R-t)/R - x}{\sigma\sqrt{(R-t)/R}}\right)
\end{aligned}
$$

STC Charts

Motivation: information "at a glance"

Computations: Pre-compute the overage levels that cause the probability of missing quota to be a specified level α:

$$\Phi\left(\frac{(Q-\mu)(R-t)/R - x}{\sigma\sqrt{(R-t)/R}}\right) = \alpha$$

- which yields

$$x = -(\mu - Q)(R-t)/R - z_\alpha \sigma \sqrt{(R-t)/R}$$

- where z_α is chosen such that $\Phi(z_\alpha) = \alpha$.

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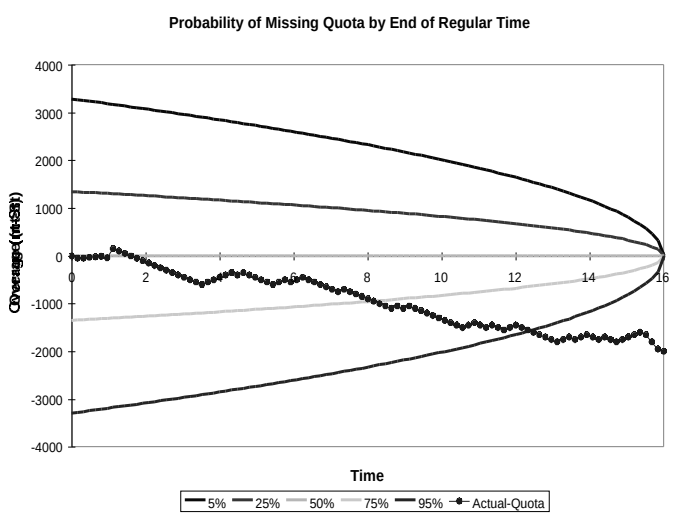
STC Chart (Q=μ)



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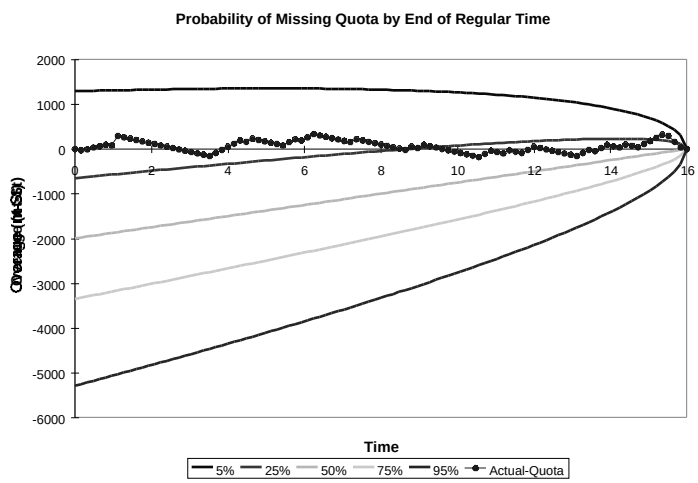
STC Chart (Q<μ)



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Long-Range Tracking

Statistics of Interest:

- μ, mean production during regular time
- σ^2, variance of regular time production

Observable Statistics: if we stop when quota is achieved, then instead of μ and σ we observe

- μ_S, mean time to make quota
- σ^2_S, variance of time to make quota

Conversion Formulas: If he have μ_S and σ_S, then we can smooth these (as shown later) and then convert to μ and σ by using

$$\mu = \frac{RQ}{\mu_S}$$

$$\sigma^2 = \frac{\sigma_S^2 RQ^2}{\mu_S^3}$$

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Smoothing Capacity Parameters

Mean Production:

$$\hat{\mu}(n) = \alpha Y_n + (1-\alpha)(\hat{\mu}(n-1) + \hat{T}_{n-1})$$
$$\hat{T}(n) = \beta(\hat{\mu}(n) - \hat{\mu}(n-1)) + (1-\beta)\hat{T}(n-1)$$

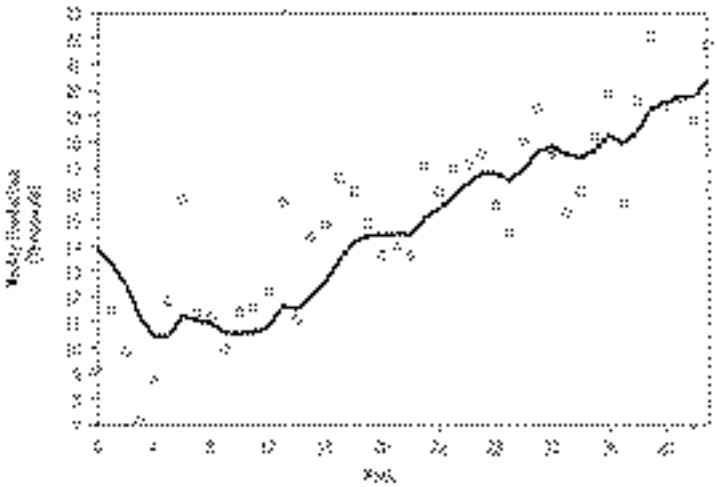
- where α and β are smoothing constants.

Production Variance:

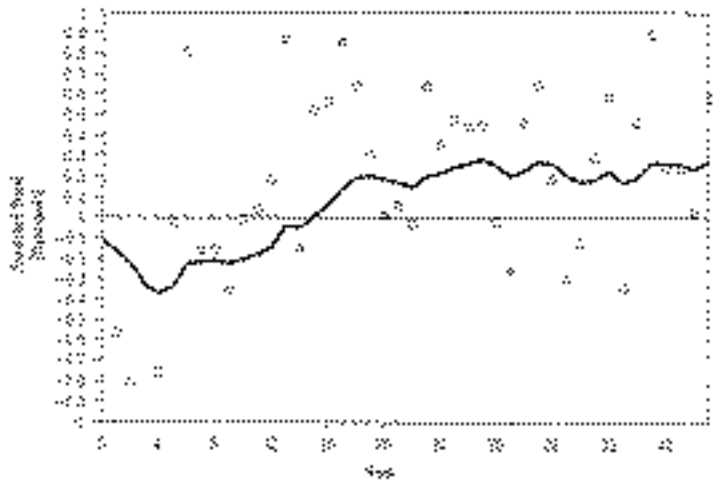
$$\hat{\sigma}^2(n) = \gamma(Y_n - \hat{\mu}(n))^2 + (1-\gamma)\hat{\sigma}^2(n-1)$$

- where γ is a smoothing constant.

LR Tracking - Mean Production



Smoothed Trend in Mean Production



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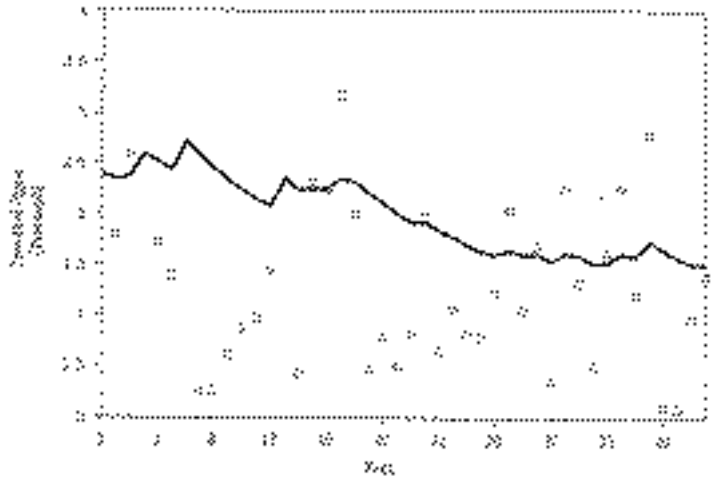
LR Tracking - Std Dev of Production



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Shop Floor Control Takeaways

General:

- SFC is more than material flow control (WIP tracking, QC, status monitoring, …)
- good SFC requires planning (workforce policies, bottlenecks, management, …)

CONWIP:

- simple starting point
- reduces variability due to WIP fluctuations
- many modifications possible (kanban, pull-from-bottleneck)

Shop Floor Control Takeaways (cont.)

Statistical Throughput Control (STC);

- tool for OT planning/prediction
- intuitive graphical display

Long Range Tracking:

- feedback for other planning/control modules
- exponential smoothing approach

An Introduction to Total Productive Maintenance (TPM)

By Venkatesh J

http://www.plant-maintenance.com/articles/tpm_intro.shtml

What is Total Productive Maintenance (TPM) ?

It can be considered as the medical science of machines. Total Productive Maintenance (TPM) is a maintenance program which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction.

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Down time for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. The goal is to hold emergency and unscheduled maintenance to a minimum.

Why TPM ?

TPM was introduced to achieve the following objectives. The important ones are listed below.

- Avoid wastage in a quickly changing economic environment.
- Producing goods without reducing product quality.
- Reduce cost.
- Produce a low batch quantity at the earliest possible time.
- Goods send to the customers must be non defective.

Similarities and differences between TQM and TPM :

The TPM program closely resembles the popular Total Quality Management (TQM) program. Many of the tools such as employee empowerment, benchmarking, documentation, etc. used in TQM are used to implement and optimize TPM.Following are the similarities between the two.

1. Total commitment to the program by upper level management is required in both programmes
2. Employees must be empowered to initiate corrective action, and
3. A long range outlook must be accepted as TPM may take a year or more to implement and is an on-going process. Changes in employee mind-set toward their job responsibilities must take place as well.

The *differences* between TQM and TPM is summarized below.

Category	TQM	TPM
Object	Quality (Output and effects)	Equipment (Input and cause)
Mains of attaining goal	Systematize the management. It is software oriented	Employees participation and it is hardware oriented
Target	Quality for PPM	Elimination of losses and wastes.

Types of maintenance :

1. Breakdown maintenance :

It means that people waits until equipment fails and repair it. Such a thing could be used when the equipment failure does not significantly affect the operation or production or generate any significant loss other than repair cost.

2. Preventive maintenance (1951):

It is a daily maintenance (cleaning, inspection, oiling and re-tightening), design to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis, to measure deterioration. It is further divided into periodic maintenance and predictive maintenance. Just like human life is extended by preventive medicine, the equipment service life can be prolonged by doing preventive maintenance.

2a. Periodic maintenance (Time based maintenance - TBM) :

Time based maintenance consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems.

2b. Predictive maintenance :

This is a method in which the service life of important part is predicted based on inspection or diagnosis, in order to use the parts to the limit of their service life. Compared to periodic maintenance, predictive maintenance is condition based maintenance. It manages trend values, by measuring and analyzing data about deterioration and employs a surveillance system, designed to monitor conditions through an on-line system.

3. Corrective maintenance (1957) :

It improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability

4. Maintenance prevention (1960):

It indicates the design of a new equipment. Weakness of current machines are sufficiently studied (on site information leading to failure prevention, easier maintenance and prevents of defects, safety and ease of manufacturing) and are incorporated before commissioning a new equipment.

TPM - History:

TPM is a innovative Japanese concept. The origin of TPM can be traced back to 1951 when preventive maintenance was introduced in Japan. However the concept of preventive maintenance was taken from USA. Nippondenso was the first company to introduce plant wide preventive maintenance in 1960. Preventive maintenance is the concept wherein, operators produced goods using machines and the maintenance group was dedicated with work of maintaining those machines, however with the automation of Nippondenso, maintenance became a problem as more maintenance personnel were required. So the management decided that the routine maintenance of equipment would be carried out by the operators. (This is Autonomous maintenance, one of the features of TPM). Maintenance group took up only essential maintenance works.

Thus Nippondenso which already followed preventive maintenance also added Autonomous maintenance done by production operators. The maintenance crew went in the equipment modification for improving reliability. The modifications were made or incorporated in new equipment. This lead to maintenance prevention. Thus *preventive maintenance* along with *Maintenance prevention* and *Maintainability Improvement* gave birth to ***Productive maintenance***. The aim of productive maintenance was to maximize plant and equipment effectiveness to achieve optimum life cycle cost of production equipment.

By then Nippon Denso had made quality circles, involving the employees participation. Thus all employees took part in implementing Productive maintenance. Based on these developments Nippondenso was awarded the distinguished plant prize for developing and implementing TPM, by the *Japanese Institute of Plant Engineers* (JIPE). Thus Nippondenso of the Toyota group became the first company to obtain the TPM certification.

TPM Targets:

P
Obtain Minimum 80% OPE.
Obtain Minimum 90% OEE (Overall Equipment Effectiveness)
Run the machines even during lunch. (Lunch is for operators and not for machines !)

Q
Operate in a manner, so that there are no customer complaints.

C
Reduce the manufacturing cost by 30%.
D

Achieve 100% success in delivering the goods as required by the customer.

S
Maintain a accident free environment.

M
Increase the suggestions by 3 times. Develop Multi-skilled and flexible workers.

Motives of TPM	1. Adoption of life cycle approach for improving the overall performance of production equipment. 2. Improving productivity by highly motivated workers which is achieved by job enlargement. 3. The use of voluntary small group activities for identifying the cause of failure, possible plant and equipment modifications.
Uniqueness of TPM	The major difference between TPM and other concepts is that the operators are also made to involve in the maintenance process. The concept of *"I (Production operators) Operate, You (Maintenance department) fix"* is not followed.
TPM Objectives	1. Achieve Zero Defects, Zero Breakdown and Zero accidents in all functional areas of the organization. 2. Involve people in all levels of organization. 3. Form different teams to reduce defects and Self Maintenance.
Direct benefits of TPM	1. Increase productivity and OPE (Overall Plant Efficiency) by 1.5 or 2 times. 2. Rectify customer complaints. 3. Reducethe manufacturing cost by 30%. 4. Satisfy the customers needs by 100 % (Delivering the right quantity at the right time, in the required quality.) 5. Reduce accidents. 6. Follow pollution control measures.
Indirect benefits of TPM	1. Higher confidence level among the employees. 2. Keep the work place clean, neat and attractive. 3. Favorablechange in the attitude of the operators. 4. Achieve goals by working as team. 5. Horizontaldeployment of a new concept in all areas of the organization. 6. Share knowledge and experience. 7. The workers get a feeling of owning the machine.

OEE (Overall Equipment Efficiency) :

OEE = A x PE x Q

A - Availability of the machine. Availability is proportion of time machine is actually available out of time it should be available.

A = (MTBF - MTTR) / MTBF.

MTBF - Mean Time Between Failures = (Total Running Time) / Number of Failures.
MTTR - Mean Time To Repair.

PE - Performance Efficiency. It is given by RE X SE.

Rate efficiency (RE) : Actual average cycle time is slower than design cycle time because of jams, etc. Output is reduced because of jams
Speed efficiency (SE) : Actual cycle time is slower than design cycle time machine output is reduced because it is running at reduced speed.

Q - Refers to quality rate. Which is percentage of good parts out of total produced sometimes called "yield".

Steps in introduction of TPM in a organization :

Step A - PREPARATORY STAGE :

STEP 1 - Announcement by Management to all about TPM introduction in the organization :

Proper understanding, commitment and active involvement of the top management in needed for this step. Senior management should have awareness programmes, after which announcement is made to all. Publish it in the house magazine and put it in the notice board. Send a letter to all concerned individuals if required.

STEP 2 - Initial education and propaganda for TPM :

Training is to be done based on the need. Some need intensive training and some just an awareness. Take people who matters to places where TPM already successfully implemented.

STEP 3 - Setting up TPM and departmental committees :

TPM includes improvement, autonomous maintenance, quality maintenance etc., as part of it. When committees are set up it should take care of all those needs.

STEP 4 - Establishing the TPM working system and target :

Now each area is benchmarked and fix up a target for achievement.

STEP 5 - A master plan for institutionalizing :

Next step is implementation leading to institutionalizing wherein TPM becomes an organizational culture. Achieving PM award is the proof of reaching a satisfactory level.

STEP B - INTRODUCTION STAGE

This is a ceremony and we should invite all. Suppliers as they should know that we want quality supply from them. Related companies and affiliated companies who can be our customers, sisters concerns etc. Some may learn from us and some can help us and customers will get the communication from us that we care for quality output.

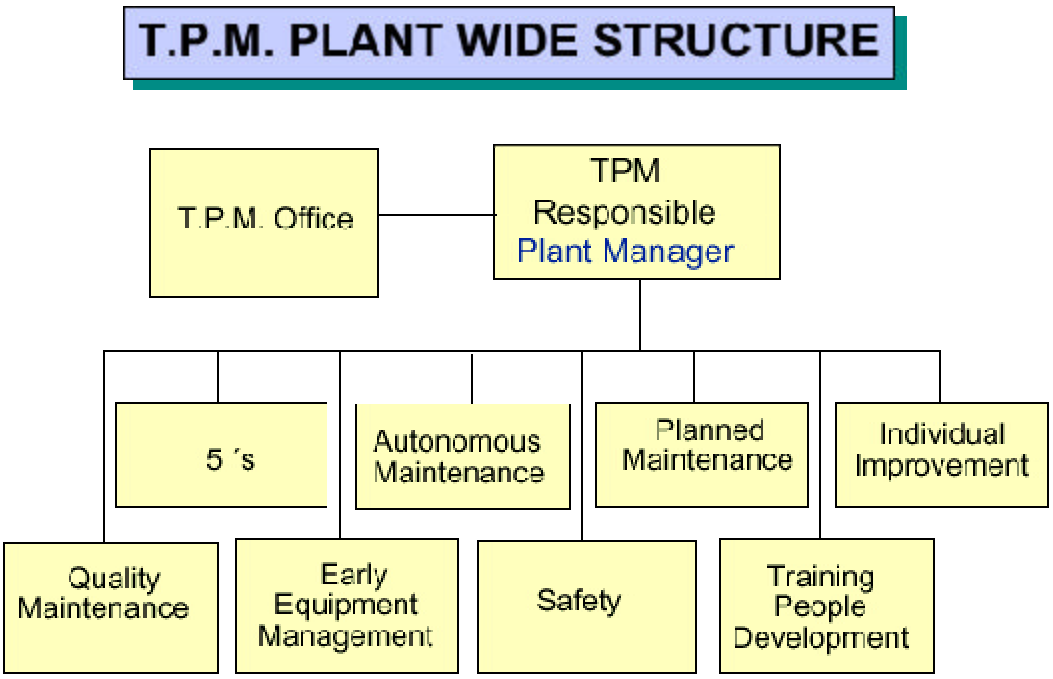
STAGE C - IMPLEMENTATION

In this stage eight activities are carried which are called eight pillars in the development of TPM activity.
Of these four activities are for establishing the system for production efficiency, one for initial control system of new products and equipment, one for improving the efficiency of administration and are for control of safety, sanitation as working environment.

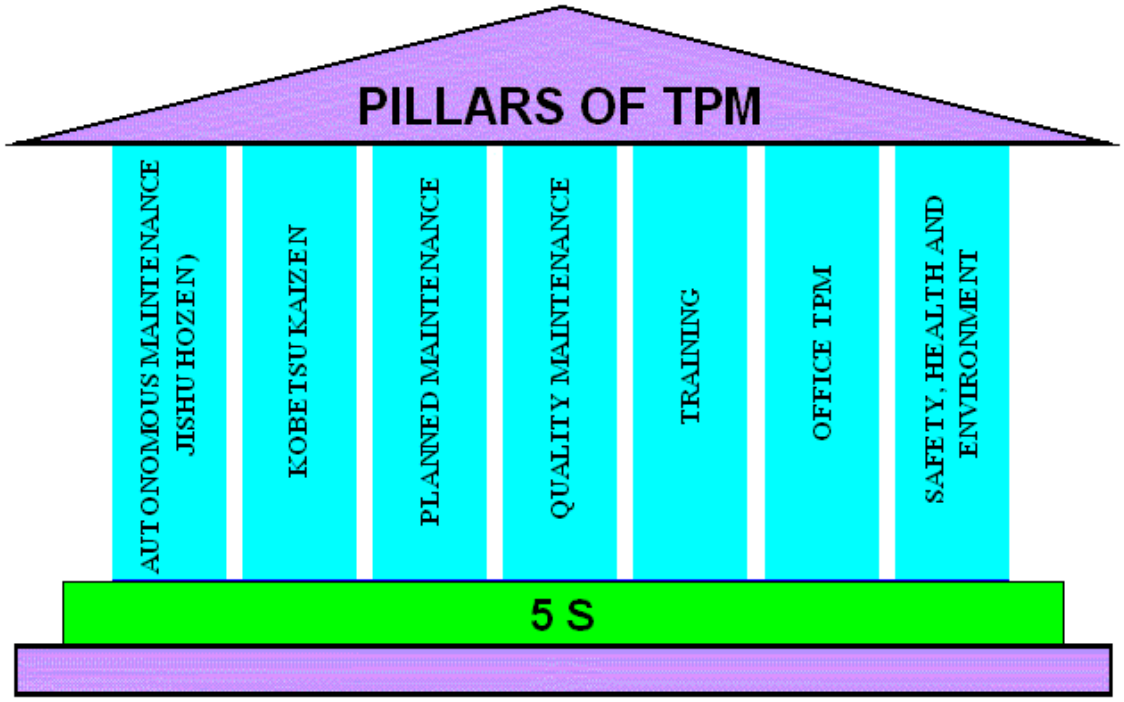
STAGE D - INSTITUTIONALISING STAGE

By all there activities one would has reached maturity stage. Now is the time for applying for PM award. Also think of challenging level to which you can take this movement.

Organization Structure for TPM Implementation:



Pillars of TPM



PILLAR 1 - 5S :

TPM starts with 5S. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement.

Japanese Term	**English Translation**	**Equivalent 'S' term**
Seiri	Organisation	Sort
Seiton	Tidiness	Systematise
Seiso	Cleaning	Sweep
Seiketsu	Standardisation	Standardise
Shitsuke	Discipline	Self - Discipline

SEIRI - Sort out :

This means sorting and organizing the items as critical, important, frequently used items, useless, or items that are not need as of now. Unwanted items can be salvaged. Critical items should be kept for use nearby and items that are not be used in near future, should be stored in some place. *For this step, the worth of the item should be decided based on utility and not cost*. As a result of this step, the search time is reduced.

Priority	Frequency of Use	How to use
Low	Less than once per year, Once per year<	Throw away, Store away from the workplace
Average	At least 2/6 months, Once per month, Once per week	Store together but offline
High	Once Per Day	Locate at the workplace

SEITON - Organise :

The concept here is that "*Each items has a place, and only one place*". The items should be placed back after usage at the same place. To identify items easily, name plates and colored tags has to be used. Vertical racks can be used for this purpose, and heavy items occupy the bottom position in the racks.

SEISO - Shine the workplace :

This involves cleaning the work place free of burrs, grease, oil, waste, scrap etc. No loosely hanging wires or oil leakage from machines.

SEIKETSU - Standardization :

Employees has to discuss together and decide on standards for keeping the work place / Machines / pathways neat and clean. This standards are implemented for whole organization and are tested / Inspected randomly.

SHITSUKE - Self discipline :

Considering 5S as a way of life and bring about self-discipline among the employees of the organization. This includes wearing badges, following work procedures, punctuality, dedication to the organization etc.

PILLAR 2 - JISHU HOZEN (Autonomous maintenance) :

This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating.

Policy :

1. Uninterrupted operation of equipments.
2. Flexible operators to operate and maintain other equipments.
3. Eliminating the defects at source through active employee participation.
4. Stepwise implementation of JH activities.

JISHU HOZEN Targets:

1. Prevent the occurrence of 1A / 1B because of JH.
2. Reduce oil consumption by 50%
3. Reduce process time by 50%
4. Increase use of JH by 50%

Steps in JISHU HOZEN :

1. Preparation of employees.
2. Initial cleanup of machines.
3. Take counter measures
4. Fix tentative JH standards
5. General inspection
6. Autonomous inspection
7. Standardization and
8. Autonomous management.

Each of the above mentioned steps is discussed in detail below.

1. Train the Employees : Educate the employees about TPM, Its advantages, JH advantages and Steps in JH. Educate the employees about abnormalities in equipments.
2. Initial cleanup of machines :
    - Supervisor and technician should discuss and set a date for implementing step1
    - Arrange all items needed for cleaning
    - On the arranged date, employees should clean the equipment completely with the help of maintenance department.
    - Dust, stains, oils and grease has to be removed.
    - Following are the things that has to be taken care while cleaning. They are Oil leakage, loose wires, unfastened nits and bolts and worn out parts.

- After clean up problems are categorized and suitably tagged. White tags is place where problems can be solved by operators. Pink tag is placed where the aid of maintenance department is needed.
- Contents of tag is transferred to a register.
- Make note of area which were inaccessible.
- Finally close the open parts of the machine and run the machine.

3. Counter Measures :
   - Inaccessible regions had to be reached easily. E.g. If there are many screw to open a fly wheel door, hinge door can be used. Instead of opening a door for inspecting the machine, acrylic sheets can be used.
   - To prevent work out of machine parts necessary action must be taken.
   - Machine parts should be modified to prevent accumulation of dirt and dust.
4. Tentative Standard :
   - JH schedule has to be made and followed strictly.
   - Schedule should be made regarding cleaning, inspection and lubrication and it also should include details like when, what and how.
5. General Inspection :
   - The employees are trained in disciplines like Pneumatics, electrical, hydraulics, lubricant and coolant, drives, bolts, nuts and Safety.
   - This is necessary to improve the technical skills of employees and to use inspection manuals correctly.
   - After acquiring this new knowledge the employees should share this with others.
   - By acquiring this new technical knowledge, the operators are now well aware of machine parts.
6. Autonomous Inspection :
   - New methods of cleaning and lubricating are used.
   - Each employee prepares his own autonomous chart / schedule in consultation with supervisor.
   - Parts which have never given any problem or part which don't need any inspection are removed from list permanently based on experience.
   - Including good quality machine parts. This avoid defects due to poor JH.
   - Inspection that is made in preventive maintenance is included in JH.
   - The frequency of cleanup and inspection is reduced based on experience.
7. Standardization :
   - Upto the previous stem only the machinery / equipment was the concentration. However in this step the surroundings of machinery are organized. Necessary items should be organized, such that there is no searching and searching time is reduced.
   - Work environment is modified such that there is no difficulty in getting any item.
   - Everybody should follow the work instructions strictly.
   - Necessary spares for equipments is planned and procured.
8. Autonomous Management :
   - OEE and OPE and other TPM targets must be achieved by continuous improve through Kaizen.
   - PDCA (Plan, Do, Check and Act) cycle must be implemented for Kaizen.

PILLAR 3 - KAIZEN :

"Kai" means change, and "Zen" means good (for the better). Basically kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen is opposite to big spectacular innovations. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are move effective in an organizational environment than a few improvements of large value. This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough procedure we eliminate losses in a systematic method using various Kaizen tools. These activities are not limited to production areas and can be implemented in administrative areas as well.

Kaizen Policy :

1. Practice concepts of zero losses in every sphere of activity.
2. relentless pursuit to achieve cost reduction targets in all resources
3. Relentless pursuit to improve over all plant equipment effectiveness.
4. Extensive use of PM analysis as a tool for eliminating losses.
5. Focus of easy handling of operators.

Kaizen Target :

Achieve and sustain zero loses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes. It also aims to achieve 30% manufacturing cost reduction.

Tools used in Kaizen :

1. PM analysis
2. Why - Why analysis
3. Summary of losses
4. Kaizen register
5. Kaizen summary sheet.

The objective of TPM is maximization of equipment effectiveness. TPM aims at maximization of machine utilization and not merely machine availability maximization. As one of the pillars of TPM activities, Kaizen pursues efficient equipment, operator and material and energy utilization, that is extremes of productivity and aims at achieving substantial effects. Kaizen activities try to thoroughly eliminate 16 major losses.

16 Major losses in a organisation:

Loss	***Category***
1. Failure losses - Breakdown loss 2. Setup / adjustment losses 3. Cutting blade loss 4. Start up loss 5. Minor stoppage / Idling loss. 6. Speed loss - operating at low speeds. 7. Defect / rework loss 8. Scheduled downtime loss	Losses that impede equipment efficiency
9. Management loss 10. Operating motion loss 11. Line organization loss 12. Logistic loss 13. Measurement and adjustment loss	Loses that impede human work efficiency
14. Energy loss 15. Die, jig and tool breakage loss 16. Yield loss.	Loses that impede effective use of production resources

Classification of losses :

Aspect	**Sporadic Loss**	**Chronic Loss**
Causation	Causes for this failure can be easily traced. Cause-effect relationship is simple to trace.	This loss cannot be easily identified and solved. Even if various counter measures are applied
Remedy	Easy to establish a remedial measure	This type of losses are caused because of hidden defects in machine, equipment and methods.
Impact / Loss	A single loss can be costly	A single cause is rare - a combination of causes trends to be a rule
Frequency of occurrence	The frequency of occurrence is low and occasional.	The frequency of loss is more.
Corrective action	Usually the line personnel in the production can attend to this problem.	Specialists in process engineering, quality assurance and maintenance people are required.

PILLAR 4 - PLANNED MAINTENANCE :

It is aimed to have trouble free machines and equipments producing defect free products for total customer satisfaction. This breaks maintenance down into 4 "families" or groups which was defined earlier.

1. Preventive Maintenance
2. Breakdown Maintenance
3. Corrective Maintenance
4. Maintenance Prevention

With Planned Maintenance we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to better maintain their equipment.

Policy :

1. Achieve and sustain availability of machines
2. Optimum maintenance cost.
3. Reduces spares inventory.
4. Improve reliability and maintainability of machines.

Target :

1. Zero equipment failure and break down.
2. Improve reliability and maintainability by 50 %
3. Reduce maintenance cost by 20 %
4. Ensure availability of spares all the time.

Six steps in Planned maintenance :

1. Equipment evaluation and recoding present status.
2. Restore deterioration and improve weakness.
3. Building up information management system.
4. Prepare time based information system, select equipment, parts and members and map out plan.
5. Prepare predictive maintenance system by introducing equipment diagnostic techniques and
6. Evaluation of planned maintenance.

PILLAR 5 - QUALITY MAINTENANCE :

It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. We gain understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, then move to potential quality concerns. Transition is from reactive to proactive (Quality Control to Quality Assurance).

QM activities is to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products. The condition are checked and measure in time series to very that measure values are within standard values to prevent defects. The transition of measured values is watched to predict possibilities of defects occurring and to take counter measures before hand.

Policy :

1. Defect free conditions and control of equipments.
2. QM activities to support quality assurance.
3. Focus of prevention of defects at source
4. Focus on poka-yoke. (fool proof system)
5. In-line detection and segregation of defects.
6. Effective implementation of operator quality assurance.

Target :

1. Achieve and sustain customer complaints at zero
2. Reduce in-process defects by 50 %
3. Reduce cost of quality by 50 %.

Data requirements :

Quality defects are classified as *customer end defects* and *in house* defects. For customer-end data, we have to get data on

1. Customer end line rejection
2. Field complaints.

In-house, data include data related to products and data related to process

Data related to product :

1. Product wise defects
2. Severity of the defect and its contribution - major/minor
3. Location of the defect with reference to the layout
4. Magnitude and frequency of its occurrence at each stage of measurement
5. Occurrence trend in beginning and the end of each production/process/changes. (Like pattern change, ladle/furnace lining etc.)
6. Occurrence trend with respect to restoration of breakdown/modifications/periodical replacement of quality components.

Data related to processes:

1. The operating condition for individual sub-process related to men, method, material and machine.
2. The standard settings/conditions of the sub-process

3. The actual record of the settings/conditions during the defect occurrence.

PILLAR 6 - TRAINING :

It is aimed to have multi-skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient know only "Know-How" by they should also learn "Know-why". By experience they gain, "Know-How" to overcome a problem what to be done. This they do without knowing the root cause of the problem and why they are doing so. Hence it become necessary to train them on knowing "Know-why". The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills are

Phase 1 : Do not know.
Phase 2 : Know the theory but cannot do.
Phase 3 : Can do but cannot teach
Phase 4 : Can do and also teach.

Policy :

1. Focus on improvement of knowledge, skills and techniques.
2. Creating a training environment for self learning based on felt needs.
3. Training curriculum / tools /assessment etc conductive to employee revitalization
4. Training to remove employee fatigue and make work enjoyable.

Target :

1. Achieve and sustain downtime due to want men at zero on critical machines.
2. Achieve and sustain zero losses due to lack of knowledge / skills / techniques
3. Aim for 100 % participation in suggestion scheme.

Steps in Educating and training activities :

1. Setting policies and priorities and checking present status of education and training.
2. Establish of training system for operation and maintenance skill up gradation.
3. Training the employees for upgrading the operation and maintenance skills.
4. Preparation of training calendar.
5. Kick-off of the system for training.
6. Evaluation of activities and study of future approach.

PILLAR 7 - OFFICE TPM :

Office TPM should be started after activating four other pillars of TPM (JH, KK, QM, PM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation. Office TPM addresses twelve major losses. They are

1. Processing loss
2. Cost loss including in areas such as procurement, accounts, marketing, sales leading to high inventories
3. Communication loss
4. Idle loss
5. Set-up loss
6. Accuracy loss
7. Office equipment breakdown
8. Communication channel breakdown, telephone and fax lines
9. Time spent on retrieval of information
10. Non availability of correct on line stock status
11. Customer complaints due to logistics
12. Expenses on emergency dispatches/purchases

How to start office TPM ?

A senior person from one of the support functions e.g. Head of Finance, MIS, Purchase etc should be heading the sub-committee. Members representing all support functions and people from Production & Quality should be included in sub committee. TPM co-ordinate plans and guides the sub committee.

1. Providing awareness about office TPM to all support departments
2. Helping them to identify P, Q, C, D, S, M in each function in relation to plant performance
3. Identify the scope for improvement in each function
4. Collect relevant data
5. Help them to solve problems in their circles
6. Make up an activity board where progress is monitored on both sides - results and actions along with Kaizens.
7. Fan out to cover all employees and circles in all functions.

Kobetsu Kaizen topics for Office TPM :

- Inventory reduction
- Lead time reduction of critical processes
- Motion & space losses
- Retrieval time reduction.
- Equalizing the work load
- Improving the office efficiency by eliminating the time loss on retrieval of information, by achieving zero breakdown of office equipment like telephone and fax lines.

Office TPM and its Benefits :

1. Involvement of all people in support functions for focusing on better plant performance
2. Better utilized work area
3. Reduce repetitive work
4. Reduced inventory levels in all parts of the supply chain
5. Reduced administrative costs
6. Reduced inventory carrying cost
7. Reduction in number of files
8. Reduction of overhead costs (to include cost of non-production/non capital equipment)
9. Productivity of people in support functions
10. Reduction in breakdown of office equipment
11. Reduction of customer complaints due to logistics
12. Reduction in expenses due to emergency dispatches/purchases
13. Reduced manpower
14. Clean and pleasant work environment.

P Q C D S M in Office TPM :

P - Production output lost due to want of material, Manpower productivity, Production output lost due to want of tools.

Q - Mistakes in preparation of cheques, bills, invoices, payroll, Customer returns/warranty attributable to BOPs, Rejection/rework in BOP's/job work, Office area rework.

C - Buying cost/unit produced, Cost of logistics - inbound/outbound, Cost of carrying inventory, Cost of communication, Demurrage costs.

D - Logistics losses (Delay in loading/unloading)

- Delay in delivery due to any of the support functions
- Delay in payments to suppliers
- Delay in information

S - Safety in material handling/stores/logistics, Safety of soft and hard data.

M - Number of kaizens in office areas.

How office TPM supports plant TPM :

Office TPM supports the plant, initially in doing Jishu Hozen of the machines (after getting training of Jishu Hozen), as in Jishu Hozen at the

1. Initial stages machines are more and manpower is less, so the help of commercial departments can be taken, for this
2. Office TPM can eliminate the lodes on line for no material and logistics.

Extension of office TPM to suppliers and distributors :

This is essential, but only after we have done as much as possible internally. With suppliers it will lead to on-time delivery, improved 'in-coming' quality and cost reduction. With distributors it will lead to accurate demand generation, improved secondary distribution and reduction in damages during storage and handling. In any case we will have to teach them based on our experience and practice and highlight gaps in the system which affect both sides. In case of some of the larger companies, they have started to support clusters of suppliers.

PILLAR 8 - SAFETY, HEALTH AND ENVIRONMENT :

Target :

1. Zero accident,
2. Zero health damage
3. Zero fires.

In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis.

A committee is constituted for this pillar which comprises representative of officers as well as workers. The committee is headed by Senior vice President (Technical). Utmost importance to Safety is given in the plant. Manager (Safety) is looking after functions related to safety. To create awareness among employees various competitions like safety slogans, Quiz, Drama, Posters, etc. related to safety can be organized at regular intervals.

Conclusion:

Today, with competition in industry at an all time high, TPM may be the only thing that stands between success and total failure for some companies. It has been proven to be a program that works. It can be adapted to work not only in industrial plants, but in construction, building maintenance, transportation, and in a variety of other situations. Employees must be educated and convinced that TPM is not just another "*program of the month*" and that management is totally committed to the program and the extended time frame necessary for full implementation. If everyone involved in a TPM program does his or her part, an unusually high rate of return compared to resources invested may be expected.